PRESSURE SENSOR, TRANSMITTER, AND TIRE CONDITION MONITORING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to a pressure sensor, a transmitter unit that has the pressure sensor, and a tire condition monitoring apparatus that has the transmitter.

For example, Japanese Laid-Open Patent Publication No. 8-94468 discloses a structure of a pressure sensor unit, in which a pressure sensor is adhered to a lead terminal that also functions as a shielding member. The pressure sensor is three-dimensionally covered by the lead terminal. This structure prevents the pressure sensor from being affected by outside electromagnetic fields and thus allows the pressure sensor to accurately measure a pressure.

However, in the apparatus disclosed in the above publication, the pressure sensor is three-dimensionally covered with the lead terminal, which also functions as a shielding member. This increases the size of the pressure sensor unit, which includes the shielding member. In other words, the structure of the publication cannot reduce a size of a pressure sensor unit that includes a shielding member.

SUMMARY OF THE INVENTION

Accordingly, it is an objective of the present invention to provide a compact pressure sensor that accurately measures a pressure. The present invention also relates to a transmitter unit having such a pressure sensor and a tire condition monitoring apparatus having such a transmitter unit.

To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, a pressure sensor having a diaphragm exposed to gas is provided. The diaphragm is covered with metal body that is spaced from the diaphragm. A predetermined voltage can be applied to the metal body.

The present invention also provides a transmitter unit having a pressure sensor, a transmitter, a casing, a lid, and a metal body is provided. The pressure sensor has a diaphragm exposed to air in a tire of a vehicle. The pressure sensor measures a pressure of the air in the tire. The transmitter wirelessly transmits data representing the air pressure measured by the pressure sensor. The casing accommodates the transmitter and the pressure sensor. The lid closes the opening of the casing. The metal body is provided on the lid. When the opening of the casing is closed with the lid, the diaphragm is covered with the metal body.

Further, the present invention provides a tire condition monitoring apparatus having a pressure sensor, a transmitter, a casing, a lid, a metal body, a reception antenna, and a receiver. The pressure sensor has a diaphragm exposed to air in a tire of a vehicle. The pressure sensor measures a pressure of the air in the tire. The transmitter wirelessly transmits data representing the air pressure measured by the pressure sensor. The casing accommodates the transmitter and the pressure sensor. The lid closes the opening of the

casing. The metal body is provided on the lid. When the opening of the casing is closed with the lid, the diaphragm is covered wit the metal body. The reception antenna receives data transmitted by the transmitter. The receiver processes data received with the reception antenna.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a block diagram showing a tire condition monitoring apparatus according to one embodiment of the present invention;

Fig. 2 is a diagrammatic view showing the structure of one of the transmitters shown in **Fig. 1**;

Fig. 3 is a block diagram showing one of the transmitters shown in **Fig. 1**;

Fig. 4 is a schematic cross-sectional view showing the pressure sensor shown in **Fig. 3**;

Fig. 5 is a cross-sectional view showing the transmitter shown in **Fig. 3**;

Fig. 6 is a cross-sectional view showing a transmitter according to another embodiment;

Fig. 7 is a cross-sectional view showing a transmitter according to another embodiment;

Fig. 8 is a diagrammatic view showing the structure of a transmitter according to another embodiment; and

Fig. 9 is a cross-sectional view showing a transmitter according to another embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A pressure sensor, transmitters, and a tire condition monitoring apparatus according to the present invention will now be described with reference to the drawings.

As shown in **Fig. 1**, the tire condition monitoring apparatus 1 includes four transmitters **30** and a receiver **40**. Each transmitter **30** is located in one of the tires **20** of a vehicle **10**. The receiver **40** is located on a body frame **11** of the vehicle **10**.

Each transmitter **30** is located in the corresponding tire **20** and is fixed, for example, to a wheel **21** of the tire **20**. Each transmitter **30** measures the condition of the corresponding tire **20**, that is, the pressure of the tire **20**. The transmitter **30** then wirelessly transmits data containing air pressure data.

The receiver **40** is located at a predetermined position on the body frame **11** and is activated by electricity of a battery (not shown) of the vehicle **10**. The receiver **40** is connected to a reception antenna **41** with a cable **42**. The receiver **40** receives data transmitted by the transmitters **30** through the reception antenna **41**.

A display **50** is located in the view of the driver of the vehicle **10**, for example, in the passenger compartment. The display **50** is connected to the receiver **40** with a cable **43**.

As shown in **Fig. 2**, each transmitter **30** is accommodated in a casing **70** that is located below a valve stem **60**. Air is injected into the tire **20** through the valve stem **60**. The casing **70** is formed into a substantially rectangular box. The casing **70** accommodates a substantially rectangular substrate **80**. Electronic elements such as a transmission controller **31**, a pressure sensor **32**, a transmission circuit **33**, a transmission antenna **34**, and a battery **35** are mounted on the substrate **80**. The substrate **80** is fixed to the bosses **71** that are integrally formed with the casing **70**. The casing **70** has a through hole (not shown) to

permit the pressure sensor **32** to measure the air pressure in the tire **20**. The casing **70** has an opening **72**, which is closed with a lid **73** for protecting the electronic elements.

As shown in **Fig. 3**, each transmitter **30** includes a transmission controller **31**, which is a microcomputer. The transmission controller **31** includes, for example, a central processing unit (CPU), a read only memory (ROM), and a random access memory (RAM). A unique ID code is registered in an internal memory, for example, the ROM, of the transmission controller **31**. The ID code is used to distinguish the associated transmitter **30** from the other three transmitters **30**.

The pressure sensor **32** measures the air pressure in the interior of the associated tire **20** and provides the transmission controller **31** with pressure data, which is obtained from the measurement. The transmission controller **31** sends data containing the air pressure data and the registered ID code to a transmission circuit **33**. The transmission circuit **33** encodes and modulates the data sent from the transmission controller **31**. The transmission circuit **33** then wirelessly transmits the data through a transmission antenna **34**. Each transmitter **30** is provided with a battery **35**. The transmission circuit **33** and the battery **35** function as a power supply circuit that supplies electricity to the transmitter **30**. The transmitter **30** is driven by electricity of the battery **35**.

As shown in **Fig. 4**, the pressure senor **32** is made of ceramic, and has an upper base **100** and a lower base **200**. A frustoconical recess **102** is formed in a central portion of the upper base **100**. As a result, a diaphragm **103** is formed in an central portion of a upper surface **101** of the upper base **100**. A first electrode **104** is formed on the lower surface of the diaphragm **103**.

A second electrode **202** is formed in a center of the upper surface **201** of the lower

base **200**. The first electrode **104** and the second electrode **202** are formed by aluminum deposition. The upper base **100** and the lower base **200** are hermitically attached to each other such that the first electrode **104** and the second electrode **202** face each other. As a result, a hermetic space **105** is defined between the first electrode **104** and the second electrode **202**. The hermetic space **105** is filled with gas having a predetermined pressure.

The diaphragm **103** is exposed to the air inside the tire **20** through the through hole (not shown) formed in the casing **70**. In other words, the diaphragm **103** is exposed to air, which is a measured gas. Therefore, when the air pressure in the tire **20** changes, the difference between the air pressure in the tire **20** and the pressure of the gas filling the hermetic space **105** is changed. Accordingly, the diaphragm **103** is flexed. Then, the distance between the first electrode **104** and the second electrode **202** is changed, which changes a capacitance between the first electrode **104** and the second electrode **202**, accordingly. Therefore, the air pressure in the tire **20** is measured based on the capacitance between the first electrode **104** and the second electrode **202**. That is, the pressure sensor **32** is a capacitance type pressure sensor.

As shown in **Fig. 5**, a metal body **500** shaped as a plate is provided on a lid **73** to close the opening **72** of the casing **70**. That is, the metal body **500** is spaced apart from the upper surface **101** of the upper base **100**, or the diaphragm **103**. In this state, the metal body **500** is provided on the inner side of the lid **73** such that the metal body **500** spreads over the diaphragm **103**. The metal body **500** preferably covers 50 to 70% of the upper surface **101** of the upper base **100**. If the metal body **500** covers the entire upper surface **101** of the pressure sensor **32**, the metal body **500** functions as a shield. As a result, the pressure sensor **32** is scarcely affected by outside electromagnetic fields. If the metal body **500** does not

cover the upper surface **101** of the pressure sensor **32**, the metal body **500** does not function as a shield. In this case, although the metal body **500** does not attenuate the radio field intensity of signals transmitted by the transmission antennas **34**, the pressure sensor **32** is vulnerable to influences of outside electromagnetic fields.

A conductive rubber piece **600** is located between the metal body **500** and the battery **35**, which functions as a power supply. When the opening **72** of the casing **70** is closed with the lid **73**, the conductive rubber piece **600** connects the metal body **500** with the battery **35**. Therefore, the conductive rubber piece **600** permits the metal body **500** covering the upper surface **101** of the pressure sensor **32** to be maintained at the same potential as the power supply potential Vdd (+3V) of the battery **35**. Therefore, pressure sensor **32** is shielded by the metal body **500**. That is, the metal body **500** shields the pressure sensor **32** against outside electromagnetic fields.

A transmitter unit includes the pressure sensor **32**, the transmitter **30**, the casing **70**, the lid **73**, and the metal body **500**.

This embodiment has the following advantages.

(1) The metal body **500** is provided on the inner side of the lid **73** closing the opening **72** of the casing **70**. The conductive rubber piece **600** is located between the metal body **500** and the battery **35**. Therefore, the conductive rubber piece **600** permits the metal body **500** overlapping the upper surface **101** of the pressure sensor **32** to be maintained at the same potential as the power supply potential Vdd (+3V) of the battery **35**. As a result, the pressure sensor **32** is shielded with the metal body **500**.

That is, this structure prevents the pressure sensor **32** from being affected by outside electromagnetic fields and thus allows the pressure sensor **32** to accurately measure the air

pressure in the tire **20**. Unlike the structure disclosed in Japanese Laid-Open Patent Publication No. 8-94468, where the pressure sensor is three-dimensionally covered with a lead terminal that also functions as a shielding member, the pressure sensor **32** is covered with the metal body **500** on the lid **73**. Therefore, the size of the pressure sensor **32** is reduced.

(2) Since the size of the pressure sensor **32** is reduced, the size of the transmitter **30** is reduced. Therefore, when attaching the tire **20** to the wheel **21**, the bead is prevented from contacting the casing **70**, which accommodates the transmitter **30**. In other words, when attaching the tire **20** to the wheel **21**, the casing **70** and the transmitter **30** are prevented from being damaged by the bead of the tire **20**.

(3) The pressure sensor **32** is scarcely affected by outside electromagnetic fields. This permits the pressure sensor **32** to accurately measure even small changes in the air pressure in the tire **20**. In other words, the present invention provides the transmitter **30**, which accurately measures the air pressure in the tire **20**. As a result, the transmitter **30** wirelessly transmits accurate air pressure data to the receiver **40**.

(4) Shielding of the pressure sensor **23** is achieved only by closing the opening **72** of the casing **70** with the lid **73** on which the metal body **500** is provided. Compared to a conventional assembly procedure, only a step for attaching the metal body **500** to the lid **73** is added. In other words, no complicated step is added to the procedure for obtaining the shielding effect. Therefore, the transmitter **30** is easily assembled with the casing **70**.

(5) The receiver **40** receives data through the reception antenna **41** and, based on the received data, causes the display **50** to display air pressure data. This informs a driver of the vehicle **10** of the accurate air pressure data. In other words, the present invention provides

the tire condition monitoring apparatus 1, which accurately measures the air pressure in the tire **20**.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

A conductive film may be formed on the upper surface **101** of the upper base **100** of the pressure sensor **32** by aluminum deposition, and the formed conductive film may be connected to the battery **35** with the metal body **500** and the conductive rubber piece **600**. This structure permits the conductive film formed on the upper surface **101** of the upper base **100** to be maintained at the same potential as the potential of the battery **35**. Therefore, pressure sensor **32** is shielded by the metal body **500**. That is, the metal body **500** shields the pressure sensor **32** against outside electromagnetic fields.

As shown in **Fig. 6**, a left end of the metal body **500** may be bent such that the left end contacts the battery **35** when the opening **72** of the casing **70** is closed with the lid **73** to shield the pressure sensor **32** with the metal body **500**. This structure permits the metal body **500** to be at the same potential as the potential of the battery **35** so that the metal body **500** shields the pressure sensor **32** against outside electromagnetic fields.

As shown in **Fig. 7**, a left end of the metal body **500** may be bent such that the bent end contacts the battery **35** when the opening **72** of the casing **70** is closed, and an engaging portion **74** for receiving a right end of the metal body **500** may be formed on the lid **73**. The right end of the metal body **500** is engaged with the engaging portion **74** so that the metal body **500** shields the pressure sensor **32**. This structure permits the metal body **500** to be at

the same potential as the potential of the battery **35** so that the metal body **500** shields the pressure sensor **32** against outside electromagnetic fields.

In an embodiment shown **Figs. 8 and 9**, the battery **35** is accommodated in a left section of the casing **70**. The substantially rectangular substrate **80** is accommodated in a right section of the casing **70**. Electronic elements such as the transmission controller **31**, the pressure sensor **32**, the transmission circuit **33**, and the transmission antenna **34** are mounted on the substrate **80**. The substrate **80** is fixed to the bosses **71** that are integrally formed with the casing **70**. The casing **70** has a through hole (not shown) to permit the pressure sensor **32** to measure the air pressure in the tire **20**. The casing **70** has an opening **72**, which is closed with a lid **73** for protecting the electronic elements.

The outer side of the lid **73** is covered with the metal body **500**. Specifically, an aluminum film is transferred to the outer surface of the lid **73**. A through hole **73a** is formed in the lid **73**. A positive terminal **35a** is connected to the power supply potential Vdd (+3V) of the battery **35**. An end portion of the positive terminal **35a** extends through the through hole **73a** and is bent toward the center of the lid **73**. The bent end of the positive terminal **35a** is connected with the metal body **500** through, for example, spot welding or soft soldering. The other end of the positive terminal **35a** is not bent and is connected with the substrate **80** through, for example, soft soldering. A negative terminal **35b** is connected to the ground potential GND (0V) of the battery **35**. An end of the negative terminal **35b** is bent and connected to the substrate with, for example, soft soldering.

This structure permits the metal body **500** to be at the same potential as the power supply potential Vdd (+3V) of the battery **35** so that the metal body **500** shields the pressure sensor **32** against outside electromagnetic fields. That is, this structure prevents the pressure

sensor **32** from being affected by outside electromagnetic fields and thus allows the pressure sensor **32** to accurately measure the air pressure in the tire **20**.

The metal body **500** may have a mesh structure. In this case, radio waves of a particular frequency can be blocked by the metal body **500** according to the size of the openings of the mesh.

In the illustrated embodiments **Figs. 1 and 7**, the potential of the metal body **500** is the same as the power supply potential Vdd (+3V) of the battery **35**. However, the potential of the metal body **500** may be the same as the ground potential GND (0V) of the battery **35**. This structure also shields the pressure sensor **32** against outside electromagnetic fields with the metal body **500**.

In all of the above embodiments, the potential of the metal body **500** is the same as the potential of the battery **35**. However, the metal body **500** may be simply provided on the lid **73** without setting the potential of the metal body **500** equal to the potential of the battery **35**.

As long as the metal body **500** has conductivity, the metal body **500** may be a conductive film.

The conductive rubber piece **600** may be replaced by a conductive adhesive. A conductive adhesive is capable of maintaining the potential of the metal body **500** to the same potential as the battery **35**.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.